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(54) ELECTRON OPTICS SYSTEM OF A MICROPROBE DEVICE

The invention relates to electron optics instrument construction and may be used in microprobe devices for fabricating micro-patterns on articles, and also in microprobe devices for studying objects.

An electron optics system (EOS) of a microprobe device, e.g. for fabricating micro-patterns on articles, is known which contains, coaxially arranged, a source of thermal electrons, two condensing lenses, a shaping lens, an aperture stop, a scanning system and a two-level deflecting system. The said electron optics system makes it possible to form an electron beam (probe) with a diameter of 500 Å at an accelerating voltage of 20 kV with a current of  $1-5 \cdot 10^{-10}$  A [1].

A disadvantage of this EOS is the low current value of the electron beam in the working plane, which does not allow it to be used for direct fabrication of articles by the planar technology method due to the low productivity.

Closest in technical substance to the invention is an EOS of a microprobe device for fabricating micro-patterns, which comprises, coaxially arranged, an

auto-emission electron source, two anodes, a condensing lens with two pole shoes, a shaping lens, a deflecting system and an aperture stop [2].

This EOS makes it possible to scan with the electron beam an area of  $4 \times 4 \text{ mm}^2$ , the beam current being  $3-4 \cdot 10^{-9} \text{ A}$  and the diameter of the beam cross-section in the working plane being equal to  $\sim 500 \text{ \AA}$ . However, the value of the current of the beam formed by the said EOS is also insufficient to ensure the necessary productivity with direct exposure of electron-resists in the process of fabricating micro-patterns on an article. In addition, the said EOS does not allow the energy of interaction of the beam electrons with the workpiece to be independently varied, since focussing of the beam in the plane of the article is ensured only at a predetermined ratio of the potential of the second anode to the potential of the first anode, and the potential of the first anode is determined by the cathode auto-electron emission current.

The aim of the invention is to increase the current of the electron beam formed by the EOS while providing independent energy regulation.

The said aim is achieved in that an electron optics system comprising, coaxially arranged, an auto-emission electron source, two anodes, a condensing lens with two pole shoes, a shaping lens, a deflecting system and an aperture stop, is fitted with at least one additional electrode, located in the region of the intermediate image of the electron source between the condensing and shaping lenses, while the anodes are situated within the condensing lens adjacent to its first pole shoe along the beam path.

The drawing shows a diagram of the device.

The EOS of a microprobe device comprises, coaxially arranged, an auto-emission electron source 1, two anodes 2 and 3, which form an accelerating gap, a magnetic condensing lens 4 with two pole shoes 5 and 6. Anodes 2 and 3 are located in condensing lens 4, the first of these 2 being mounted directly adjacent to first pole shoe 5. Aperture stop 8 is located in the principal

plane of shaping lens 7, and one or several auxiliary electrodes 10, connected to voltage source 9, are introduced ahead of shaping lens 7 and located in the region of the intermediate image of electron source 1. Specimen 11 is situated after the shaping lens 7, while deflecting system 12 is within its boundaries.

The device operates in the following manner.

Auto-emission electron source 1 emits a beam of electrons either as a result of cold auto-electron emission, or as a result of mixed autothermal emission. In the latter case, the cathode is heated to a temperature of the order of 1500°C. In both cases, emission is caused by applying a potential difference between cathode 1 and first anode 2 of the accelerating gap, which is placed under a more positive potential than the cathode. The electrons emitted from source 1 are accelerated, commencing from the moment they are emitted from the cathode and ending at the moment of their exit from the field of the accelerating gap, with second anode 3 placed under a positive potential relative to first anode 2. However, the accelerating gap operates in conditions such that it forms only a virtual image of the electron source, located at a small distance. The arrangement of anodes 2 and 3 within condensing lens 4, directly adjacent to the first pole shoe 5 of condensing lens 4, ensures that the virtual image of electron source 1 is brought as close as possible to condensing lens 4, which converts this virtual image into a real intermediate image of the electron source. With minimal beam current losses the coefficients of central aberrations of the accelerating gap and the magnetic condensing lens 4 will be small, in consequence of the said virtual image being located close (5-7 mm) to the outer boundary surface of pole shoe 5 of condensing lens 4 and the entry aperture of first anode 2. The real intermediate image, formed by the accelerating gap - condensing lens system, is located on the optical axis in the region of auxiliary electrodes 10. As the electron beam passes through electrodes 10, the energy of the beam electrons can be varied in

accordance with the required energy of interaction with specimen 11. The beam can be accelerated or retarded by regulating the voltage supplied from source 9 to the said electrodes. Their position in relation to the real intermediate image of electron source 1 guarantees that the intrinsic central aberrations have only a small effect on the size of this image owing to the angles of convergence of the electrons being small and the trajectories of the electrons forming this real image being actually paraxial. The real intermediate image of the electron source is directed onto the surface of specimen 11 with reduction by means of shaping lens 7. Aperture stop 8, which delimits the electron beam and is mounted in the principal plane of shaping lens 7, ensures that the predetermined cross-sectional diameter of the electron probe is provided in the plane of specimen 11. Deflecting system 12 displaces the shaped electron beam over the surface of specimen 11 in accordance with a treatment or investigation programme.

The presently proposed electron optics system of a microprobe device thus makes it possible, by bringing the condensing lens as close as possible to the plane of the virtual image of the electron source and appropriate arrangement of the auxiliary electrodes, which regulate final beam energy, to obtain maximum probe beam current with a predetermined beam cross-sectional diameter in the plane of the specimen, providing the possibility of independently adjusting electron beam energy to the required value in relation to the energy of electrons at the exit from the accelerating gap. Calculations which have been made show that with a beam diameter in the plane of the article of the order of 500-1000 Å, the presently proposed EOS makes it possible to obtain a probe beam current of  $1-5 \cdot 10^{-7}$  A with an angular emission current density of  $130 \cdot 10^{-6}$  A/sr, emission currents of  $10 \cdot 10^{-6}$  A/sr and a beam electron energy of 20 keV. This is approximately 100 times greater than in the EOS adopted as the prototype, and the productivity of the device for fabricating micropatterns on an article is

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increased by the same factor.

The presently proposed EOS can be utilized widely in electron-beam microprobe instruments for investigating and treating objects, where it makes it possible to improve the quality and increase the productivity of investigations and treatment by increasing the shaping beam current while providing independent regulation of its energy in the plane of interaction with the specimen.

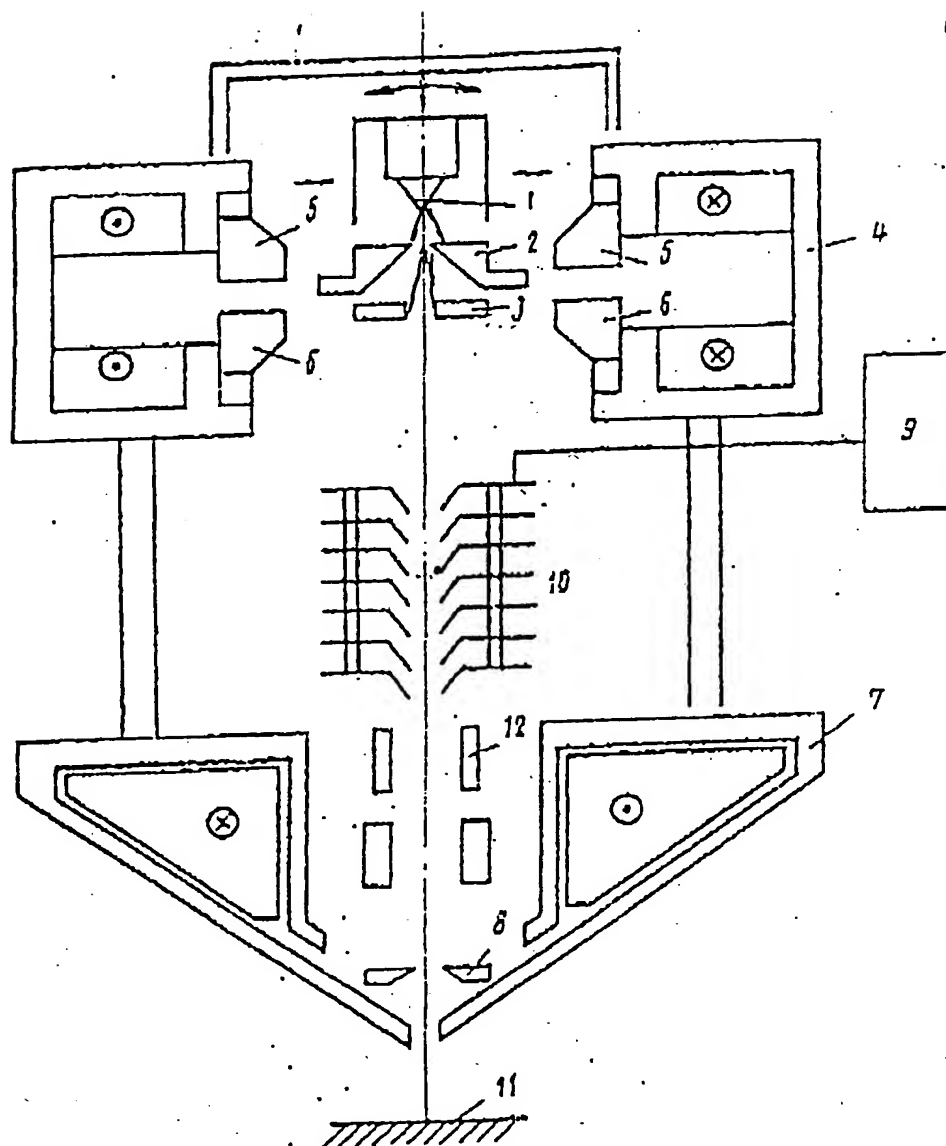
#### C l a i m

An electron optics system of a microprobe device, comprising, coaxially arranged, an auto-emission electron source, two anodes, a condensing lens with two pole shoes, a shaping lens, a deflecting system and an aperture stop, characterized in that, with the aim of increasing the electron beam current while providing independent regulation of electron energy, it is provided with at least one auxiliary electrode, situated in the region of the intermediate image of the electron source between the condensing and shaping lenses, while the anodes are located within the condensing lens adjacent to its first pole shoe along the beam path.

Sources of information considered in the examination

1. J. Chang, B. Wallmann. A computer-controlled electron beam machine for microcircuit fabrication. IEEE Trans. Electron Devices, v. ED-12, 1977, pp 629-635.
2. G. Sille, B. Astrand. A field emitter electron beam exposure system. Phys. Scripta, 1978, 18, 367-371 (example of prior art).

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